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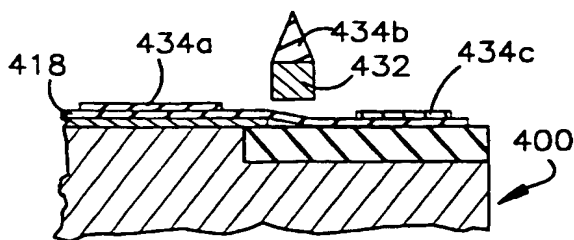
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(54) Title: COMPOUND APEX FOR VEHICLE TIRE



(57) Abstract: A pneumatic radial ply tire (500) comprises a tread (510), a belt structure (512), and a carcass (514). The carcass (514) has a radial ply (518) and two bead sections (530A, 530B). Each bead section (530A, 530B) has a bead (532) and a component apex (534) with an inner apex (534A), a middle apex (534B) and an outer apex (534C).

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COMPOUND APEX FOR VEHICLE TIRE

TECHNICAL FIELD

5 The present invention relates to an improved design for a radial ply automobile tire, and more specifically to an improved apex for a radial ply automobile tire.

BACKGROUND OF THE INVENTION

A conventional radial-ply automobile tire includes radial plies that are wrapped around two annular inextensible beads. In the tire making process, a green tire carcass ("green" meaning as yet uncured and still tacky) is built by sliding a green innerliner and radial ply over a tire "building drum" (or "building mandrel"). Two beads (each comprising a cable of steel filaments encased in green rubber) are then slid over the carcass, one at each side. The portions of the plies that extend beyond the beads are then turned up around the beads, forming "turn-ups". Then, the portion of the plies between the beads is expanded radially outward so as to contact the ply turn-ups. The annular cross-sectionally triangular rubber filler bounded by the turned up ply and the bead is called an "apex".

There are two methods of incorporating the apex during the tire-making process. In the "pre-apexing" method, an apexing machine adheres an annular triangular apex to an annular bead. The bead, with the apex still adhering to it, is slid over the carcass on the building drum. The plies are then turned up and expanded as mentioned above, so that the apex is surrounded by the bead from below and by the plies from the sides.

In the "flat application of apex" method, the apex is circumferentially laid down onto the carcass while on the building drum. The apex is laid down as a triangular strip of green rubber ("gum strip") lying horizontally on the carcass, next to the bead, so that one of its tacky long flat sides adheres to the tacky green carcass, and its short base is close to, and faces, the bead. When the portion of the plies between the beads is expanded outward, the apex's wedge profile swings around 90 degrees, and rests atop the bead, aligned vertically.

The choice of triangular dimensions and material properties of the apex affects the performance of the tire, such as tire weight, sidewall stiffness, handling, ride comfort, flexural heat, material fatigue, and tire life. For example, since the apex extends up much of the length of the sidewall, increasing the stiffness of the apex increases the stiffness of the sidewall, yielding less sidewall flexing and hence less flexural heat and material

fatigue, but at the cost of a rougher ride. Increasing the apex's radial length (so that it travels farther up the sidewall) further stiffens the sidewall and improves handling, which is beneficial for "high performance" tires.

5 Tire designers at Goodyear Tire and Rubber Company have found that they would have wider choice of, and tighter control over, tire performance if they had wider flexibility in choice of apex design -- that is, if they could specify longer apexes than conventionally used, and apexes with multiple layers of different material ("compound apexes").

However, in the pre-apexing method, the radial length of the apex is limited by inadequacies of splicing and by the tendency of the apex profile to bend at its tip, called
10 "curl-over". Apex splices, where the ends of a length of extruded rubber are spliced together to form an annular apex, are imperfect. Apex curl-over and splice imperfection are aggravated by longer radial length and softer material.

The "flat application of apex" method does not have the radial length limitation experienced by the pre-apexing method, because its apex is laid horizontally against the
15 carcass. However, it does suffer from entrapped air which can cause internal delaminations.

The "pre-apexing" method is not suitable for making compound apexes, because the compound extrusion required for such an apex is complex to extrude and prone to deformation while standing vertical on the bead in the soft green state. The "flat
20 application of apex" method is not suitable for making compound apexes because increasing the number of apex layers increases process time and requires a more complex extruder in the building drum area.

The following patents disclose bead assemblies having either a multilayered apex, a rubber material adjacent to an apex, or a flat rubber material between the bead and ply.
25 U.S. Patent No. 4,319,943 discloses a method of securing a bead filler material to a bead by positioning "bead filler portions" (apex) on top of "reinforce material" (plies) on either side of the bead bundle, and folding the reinforce material around the bead bundle. U.S. Patent No. 4,934,431, in Figure 3, discloses a bead filler 6 (apex) disposed above a ring of bead wire 3 (bead) and a "bead reinforcing layer 8 disposed within the folded portion
30 of the carcass 4 and extending about the bead wire 3" wherein the reinforcing layer 8 may be composed of cords of carbon fiber with a rubber latex adhesive. U.S. Patent No. 4,227,563 discloses a tire in which "a first filler element 78 is provided to separate the

turnup 30 from both the apex strip 70 and the carcass ply 28" and which also has second and third filler elements 84, 86. U.S. Patent No. 5,374,324 discloses an apex of triangular cross-section formed of multiple apex leafs radially contacting each other. U.S. Patent No. 5,309,971 discloses a bead assembly having a rubber bead filler 84 (apex) and a reinforced rubberized ply flipper 86. U.S. Patent No. 5,221,385 discloses a tire having a bead core 5 (bead), a bead filler 6 (apex), and a rubber sheet 13. U.S. Patent No. 3,163,683 discloses a tire bead assembly having a bead core, an apex and a gum tie strip of uncured rubber material. U.S. Patent No. 4,319,943 discloses a prior art bead subassembly (Fig. 1A) having bead filler portions 30, 32 on the top surfaces of material wings (sections of ply) axially spaced from the bead bundle annular side surfaces 16,18.

SUMMARY OF THE INVENTION

The present invention relates to a method of building a green tire carcass by wrapping a ply having a pair of spaced preassembled inner apexes around a building drum. Then, a pair of beads with preassembled middle apexes are mounted circumferentially over the ply to a location axially outward from the inner apexes. Next, the middle section of the ply between the inner apexes is expanded radially outward to bring the inner apexes against the middle apexes. Preferably, the ply has a pair of preassembled outer apexes, each outwardly spaced from one of the inner apexes. Each of the beads is positioned with the preassembled middle apexes between corresponding inner and outer apexes. Next, the ply turnup portions of the ply are turned up to bring the of outer apexes against the corresponding middle apexes.

Preferably, the inner apexes and the outer apexes have a rectangular cross-section, and the middle apexes have a substantially triangular cross-section. The inner apexes extend radially outward further than the outer apexes and the middle apexes extend radially outward less than the outer apexes. The inner apexes, the middle apexes and the outer apexes are selected from a material of the group consisting essentially of green rubber, cured rubber, and combinations thereof.

Also according to the invention, a pneumatic radial ply tire comprises a tread, a belt structure, and a carcass. The carcass has a radial ply and two bead sections. The tire is characterized by each bead section having a bead and a compound apex with a inner apex and an middle apex. The compound apex preferably also has a outer apex. The inner apex and the outer apex have a substantially rectangular cross-section, and the middle

apex has a substantially triangular cross-section. Preferably, the inner apex extends radially outward further than the outer apex and the middle apex extends radially outward less than the outer apex. The inner apex, the middle apex and the outer apex are each of a material selected from the group consisting essentially of green rubber, cured rubber and combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. The drawings are intended to be illustrative, not limiting. Certain elements in some of the drawings may be illustrated not-to-scale for illustrative clarity.

In the drawings, the hundredth's place of each reference number usually matches the figure number, and similar elements are usually referred to by similar reference numbers. For example, element 199 in **FIGURE 1**, element 299 in **FIGURE 2**, and element 399 in **FIGURE 3** usually indicate corresponding or substantially similar elements.

In a single drawing, similar elements may be assigned the same number. For example, both beads of the same tire may be assigned the same numeral.

For illustrative clarity, the cross-sectional views presented herein may be "near-sighted" cross-sectional views, omitting certain background lines that would otherwise be visible in a true cross-sectional view.

The structure, operation, and advantages of the invention will become further apparent upon consideration of the following description taken in conjunction with the accompanying drawings, wherein:

FIGURE 1A shows a meridional cross-section of a typical conventional radial ply pneumatic tire;

FIGURE 1B shows a cross-section of the bead section of **FIGURE 1A**;

FIGURES 2A-2H illustrate the steps of the prior art "positive crown" method of building a green carcass, entailing the "pre-apexing" method of affixing an apex onto a bead;

FIGURES 3A-3G illustrate the steps of the prior art "negative crown" method of building a green carcass, entailing the "flat application of apex" method of affixing the apex onto a bead;

FIGURES 4A-4I illustrate the steps of building a green carcass according to the present invention;

FIGURE 5A shows a meridional cross-section of a finished radial ply pneumatic tire according to the present invention; and

5 **FIGURE 5B** shows a cross-section of the bead section of **FIGURE 5A**.

DEFINITIONS

"Bead" means an annular tensile member that is associated with holding the tire to the rim. The beads are wrapped by ply cords and shaped, with or without other reinforcement elements such as flippers, chippers, apexes or fillers, toe guards and
10 chafers.

"Belt structure" means at least two annular layers or plies of parallel cords, woven or unwoven, underlying the tread, unanchored to the bead, and having both left and right cord angles in the range from 18 to 30 degrees relative to the equatorial plane of the tire.

"Meridional" refers to a laterally disposed curved line that lies in a plane that includes
15 the axis of the tire.

"Ply" means a cord-reinforced layer of rubber-coated radially deployed or otherwise parallel cords.

"Radial" and "radially" mean in a direction perpendicular to the axis of rotation of the tire.

20 "Radial ply tire" means a belted or circumferentially restricted pneumatic tire in which at least one ply has cords which extend from bead to bead.

"Sidewall" is the portion of a tire between the tread and the bead.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1A shows a meridional cross-section of a typical conventional radial ply tire
25 **100**, comprising a tread **110**, a belt structure ("belts") **112** comprising one or more belts, and a carcass **114**. The carcass **114** has an innerliner **116**, at least one radial ply **118**, two sidewalls **120A,120B**, and two identical bead sections **130A,130B**.

FIGURE 1B shows a cross-section of the bead section **130A** of **FIGURE 1A**. The reference numbers match those of **FIGURE 1A**. It should be understood that the
30 construction of the bead section **130B** (not shown) is the same as that of the bead section **130A**. The bead section **130A** includes a bead **132** comprised of a bundle of wound steel filament in a rubber matrix. The ply **118** is wrapped around the bead, forming a ply inner

section **118A** and a ply turnup **118B**. An apex **134** of rubber is surrounded by the bead **132**, the ply inner section **118A** and the ply turnup **118B**.

In the tire building process, there are two methods of building a green tire carcass ("green" meaning as yet uncured and still tacky), which differ in how the apex is affixed to the bead. The "positive crown" method of building a green carcass includes the "pre-apexing" method of affixing the apex. The "negative crown" method of building a green carcass includes the "flat application of apex" method of affixing the apex.

FIGURES 2A-2H diagrammatically illustrate the steps of the prior art "positive crown" method of building a green carcass, entailing the "pre-apexing" method of affixing an apex onto a bead, showing a cross-section of a portion of a first stage tire building drum **200** as tire components are added and shaped. Although the following description is described in terms of only one side of the tire, it should be understood that the procedure applies to the other side of the tire (not shown) as well.

The drum **200** has an axially-central metal surface **242**, and an inflatable bladder **244** along the axially-outer portion of its surface. As shown in **FIGURE 2A**, a green rubber innerliner **216** and then a green ply **218** (comprised of inextensible polymer cords in a green rubber matrix) are slid over the building drum **200**. Then, as shown in **FIGURE 2B**, swab down paddles **246** swing down (as shown by arrow **252**) to press the down the outer portion of the innerliner **216** and the ply **218** and then swing back up (as shown by arrow **253**). Then, as shown in **FIGURE 2C**, an apexing machine (not shown) preassembles (adheres) a triangular green rubber apex **234** over a bead **232** (comprising a cross-sectionally square bundle of wire filaments in a green rubber matrix). Then, as shown in **FIGURE 2D**, the bead **232**, with the apex **234** still adhering to it, is spliced to form a ring and is positioned circumferentially around the ply **218**. Then, as shown in **FIGURE 2E**, the bladder **244** is inflated to turn up the radially-outer portion of the ply **218**, forming a ply turnup **218B** which bends around the bead **232** and the apex **234**. Then, as shown in **FIGURE 2F**, a green sidewall **220** is affixed over (adhered to) the ply **218**. Then, as shown in **FIGURE 2G**, the resulting assembly is removed from the building drum **400**. The resulting assembly, including the innerliner **216**, the ply **218**, the bead **232** and the apex **234**, is called a green carcass **214**. Then, as shown in **FIGURE 2H**, the green carcass **214** is inflated to a toroidal shape, and its radially-outer surface is pressed against a tread and belt package (not shown).

In subsequent steps, the resulting assembly is stitched (rolled with a roller) to remove air pockets and to press internal surfaces together to yield good adhesion between adjacent materials, and the resulting assembly is inserted into a mold to cure under heat and pressure. During the aforementioned shaping process, and especially during curing, when
5 the green rubber matrix of the bead 232 temporarily softens, the bead's previously square cross-sectional profile becomes semicircular (flat top and round bottom) as it is in the final tire (as shown as bead 132 in **FIGURE 1B**).

The advantages of having the flexibility to design a radially long apex and an apex of multiple layers of different material ("compound apex") were described in the
10 Background section above. Unfortunately, in the pre-apexing method, described above, the apex must be short and stiff, due to splicing imperfection and the tendency for "curl-over" (both of which are aggravated by increased apex radial length and apex softness). Also, the pre-apexing method is not suitable for making compound apexes, because compound apexes are complex to extrude and prone to deformation while standing vertical
15 in the soft green state.

FIGURES 3A-3F diagrammatically illustrate the steps of the prior art "negative crown" (or "flat building") method of building a green carcass, entailing the "flat application of apex" method of affixing the apex onto the bead, showing a cross-section of a portion of a first stage tire building drum 300 as tire components are added and shaped.
20 Although the following description is described in terms of only one side of the tire, it should be understood that the procedure applies to the other side of the tire (not shown) as well.

The drum 300 has an expandable metal central surface 342 around the axially-center portion of its surface, and an inflatable bladder 344 around the axially-outer portion of its
25 surface. As shown in **FIGURE 3A**, a green rubber innerliner 316 and then a green ply 318 are wrapped around (over) the building drum 300. A bead 332 (same as bead 232 in **FIGURE 2B**) is positioned around, but not touching, the ply. Then, as shown by the arrows in **FIGURE 3B**, the central surface 342 is expanded radially outward to tighten against the ply 318, and the axially-inner portion of the bladder 344 is expanded radially
30 outward to tighten against the bead 332. Then, as shown in **FIGURE 3C**, an apex 334 (a substantially-triangular strip of green rubber "gum strip") is laid over the green ply 318, lying "flat" on its side (from which this apex application method gets its name), so that

one of its tacky sides adheres to the tacky green ply 318. Then, as shown in **FIGURE 3D**, the bladder 344 is inflated to turn up the radially-outer portion of the ply 318, forming a ply turnup 318B which bends around the bead 332 and the apex 334. An undesirable air pocket 354 is formed between the bead 342, the apex 344 and the ply turnup 318B, which is only partially removed by a "stitching" roller. Then, as shown in **FIGURE 2E**, a green sidewall 320 is adhered over the ply 318. The resulting assembly, shown in **FIGURE 3F**, including the innerliner 316, the ply 318, the bead 332 and the apex 334, is called a green carcass 314.

The green carcass 314 is removed from the first stage building drum and is mounted on a "second stage machine" (not shown) where it is inflated (reshaped) to a toroidal shape, as shown in **FIGURE 3G**, and its radially-outer surface is pressed against a tread and belt package (not shown). During this reshaping, the apex 334 swings around 90 degrees to rest vertically atop the bead 332. In subsequent steps (as with the "positive crown" method), the resulting assembly is "stitched" (to remove air pockets and adhere adjacent internal surfaces together) and inserted into a mold to cure under heat and pressure to become a finished tire. As in the positive crown method, during the shaping and molding processes, the bead acquires a semicircular cross-sectional profile.

The advantages of having the flexibility to design a compound apex were described in the Background section above. Unfortunately, the "flat application of apex" method, described above, is not suitable for making compound apexes because increasing the number of apex layers would increase process time and extruder complexity. Also, the "flat application of apex" method suffers from entrapped air (originating from the air pocket 354 in **FIGURE 3D**) which can cause internal delaminations.

FIGURES 4A-4E diagrammatically illustrate the steps of building a green carcass according to the present invention, showing a cross-section of a portion of a tire as tire components are added and shaped. Although the following description is described in terms of only one side of the tire carcass, it should be understood that the procedure applies to the other side of the tire carcass (not shown) as well.

"Off line" (i.e. before reaching a building drum), as shown in **FIGURE 4A**, an axially-inner apex 434A and an axially-outer apex 434C are preassembled (applied, adhered) to a ply 418 in the form of thin cross-sectionally rectangular "even gum strips" of green rubber lying flat over the ply. Then, as shown in **FIGURE 4B**, an innerliner

416 and then the ply 418 are wrapped around a building drum 400. The drum 400 is similar to the drum 300 (FIGURES 3A-3F) used in the "negative crown" tire building method. The drum 400 has an expandable axially-central metal surface 442 and an inflatable bladder 444 along the axially-outer portion of its surface. Then, as shown in
5 FIGURE 4C, an apexing machine (not shown) preassembles (adheres) a substantially-cross-sectionally triangular green rubber middle apex 434B over a bead 432 (comprising a cross-sectionally square bundle of wire filaments in a green rubber matrix). Then, as shown in FIGURE 4D, the bead 432, with the apex 434 still adhering to it, is spliced to form a ring and is positioned around (but not touching) the ply 418 between the inner apex
10 434A and the outer apex 434C. Then, as shown by the arrows in FIGURE 4E, the central surface 442 is expanded radially outward to tighten against the innerliner 416 and the ply 418, and the axially-inner portion of the bladder 444 is expanded radially outward to tighten against the bead 432. Then, as shown in FIGURE 4F, the bladder 444 is inflated to turn up the axially-outer portion of the ply 418, thus bringing the outer apex
15 434C up against the middle apex 434B, forming a ply turnup 418B which bends over the bead 432 and the three apexes 434A-C. Then, as shown in FIGURE 4G, a green sidewall 420 is adhered over the ply 418. The resulting assembly, shown in FIGURE 4H, including innerliner 416, ply 418, bead 432 and apexes 434A-C, is called a green carcass 414.

20 The green carcass 414 is removed from the first stage building drum and is mounted on a "second stage machine" (not shown) where it is inflated (thus reshaped) to a toroidal shape, as shown in FIGURE 4I, and the radially-outer surface of the carcass 414 is pressed against a tread and belt package (not shown). This reshaping straightens out the inner apex 434A and the outer apex 434C. Apexes 434A-C, adhering together (partially
25 by their own tackiness), comprise a compound apex 434. In subsequent steps, the resulting assembly is "stitched" (to remove air pockets and adhere adjacent internal surfaces together) and inserted into a mold to cure under heat and pressure to become a finished tire.

30 The three apexes 434A-C are of rubber, and can be of the same or different rubber materials. The rubber materials can be either green rubber (pre-cured), cured thermoset rubber (i.e. does not resoften when heated), or thermoplastic rubber (i.e. resoften when heated). To illustrate the design flexibility of the compound apex of the present invention,

a compound apex can be comprised of an inner apex of thermoplastic, a middle apex of green rubber, and an outer apex of cured rubber.

FIGURE 5A shows a meridional cross-section of a finished radial ply pneumatic tire **500** according to the present invention, comprising a tread **510**, a belt structure ("belts") **512** comprising one or more belts, and a carcass **514**. The carcass **514** has an innerliner **516**, at least one radial ply **518**, two sidewalls **520A, 520B**, and two identical bead sections **530A, 530B**.

FIGURE 5B shows a cross-section of the bead section **530A** of **FIGURE 5A**. It should be understood that the cross-section of the bead section **530B** (not shown) is the same as that of the bead section **530A**. The bead section **530A** includes a bead **532**. The ply **518** is wrapped around the bead, forming a ply axially-inner section **518A** and a ply turnup **518B**. A compound apex **534** is comprised of an axially-inner apex **534A**, an axially-middle apex **534B** and an axially-outer apex **534C**, and is surrounded by the bead **532**, the ply inner section **518A** and the ply turnup **518B**.

Of the three apexes **534A-C**, the inner apex **534A** is typically cross-sectionally the longest and extends radially farthest outward, and the middle apex **534B** is typically cross-sectionally the shortest and extends radially outward the least, although this is not necessary.

Although the compound apex **534** of the present embodiment includes an outer apex **534C**, it is within the scope of the present invention for the compound apex not to include the outer apex but only the inner apex **534A** and the middle apex **534B**.

The three materials for the three apexes **434A-C** can be chosen to achieve certain tire design characteristics (such as stiffness and handling characteristics), which is not possible with the conventional tire building methods. The compound apex **534** can be very long, because its longest component (the inner apex **434A**) lies on its side while in the green state. The greater the flexibility of apex length and the greater the flexibility in selecting apex material (both of which are afforded by this invention), the greater the flexibility of, and control over, tire characteristics.

Since the inner apex **434A** and the outer apex **434C** are laid onto the ply **434** off-line (i.e. before mounting the ply **418** on the building drum **400**), their application does not impede manufacturing throughput.

While the invention has been described in combination with embodiments thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and scope of the appended claims.

CLAIMS

1. A method of building a green tire carcass (414) comprising the steps of:

wrapping a ply (418), having a pair of spaced preassembled inner apexes (434A),
5 around a building drum (400);

mounting a pair of beads (432) with preassembled middle apexes (434B)
circumferentially over the ply (418) to a location axially outward from the inner apexes
(434A); and

expanding a middle section (418A) of the ply (418) between the inner apexes
10 radially outward to bring the inner apexes (434A) against the middle apexes (434B).

2. The method of building the green tire carcass (414) of Claim 1 wherein:

the ply (418) has a pair of preassembled outer apexes (434C), each outwardly
spaced from one of the inner apexes;

positioning each of the beads with the preassembled middle apexes between
15 corresponding inner and outer apexes; and

turning up a pair of ply turnup portions (418B) of the ply (418) to bring the of
outer apexes (434C) against the corresponding middle apexes (434B).

3. The method of Claim 2 wherein:

the inner apexes (434A) and the outer apexes (434C) have a rectangular cross-section,
20 and the middle apexes (434B) have a substantially triangular cross-section.

4. The method of Claim 2 wherein:

the inner apexes (434A) extend radially outward further than the outer apexes
(434C), and

the middle apexes (434B) extend radially outward less than the outer apexes.

25 5. The method of Claim 2 including the step of:

selecting the inner apexes (434A), the middle apexes (434B) and the outer apexes
(434C) from a material of the group consisting essentially of green rubber, cured rubber,
and combinations thereof.

6. A pneumatic radial ply tire (500) comprising:

30 a tread (510), a belt structure (512), and a carcass (514);

wherein the carcass (514) has a radial ply (518) and two bead sections
(530A,530B); and

wherein the tire (500) is characterized by:

each bead section (530A,530B) having a bead (532) and a compound apex (534) with a inner apex (534A) and an middle apex (534B).

5 7. The radial ply tire (500) of Claim 6 further characterized in that the compound apex (534) has an outer apex (534C).

8. The radial ply tire (500) of Claim 7 further characterized in that:

the inner apex (534A) and the outer apex (534C) have a substantially rectangular cross-section, and the middle apex (534B) has a substantially triangular cross-section.

9. The radial ply tire (500) of Claim 8 characterized in that:

10 the inner apex (534A) extends radially outward further than the outer apex (534C),
and

the middle apex (534B) extends radially outward less than the outer apex.

10. The radial ply tire (500) of Claim 9 characterized in that:

the inner apex (534A), the middle apex (534B) and the outer apex (534C) are each of a
15 material selected from the group consisting essentially of green rubber, cured rubber and combinations thereof.

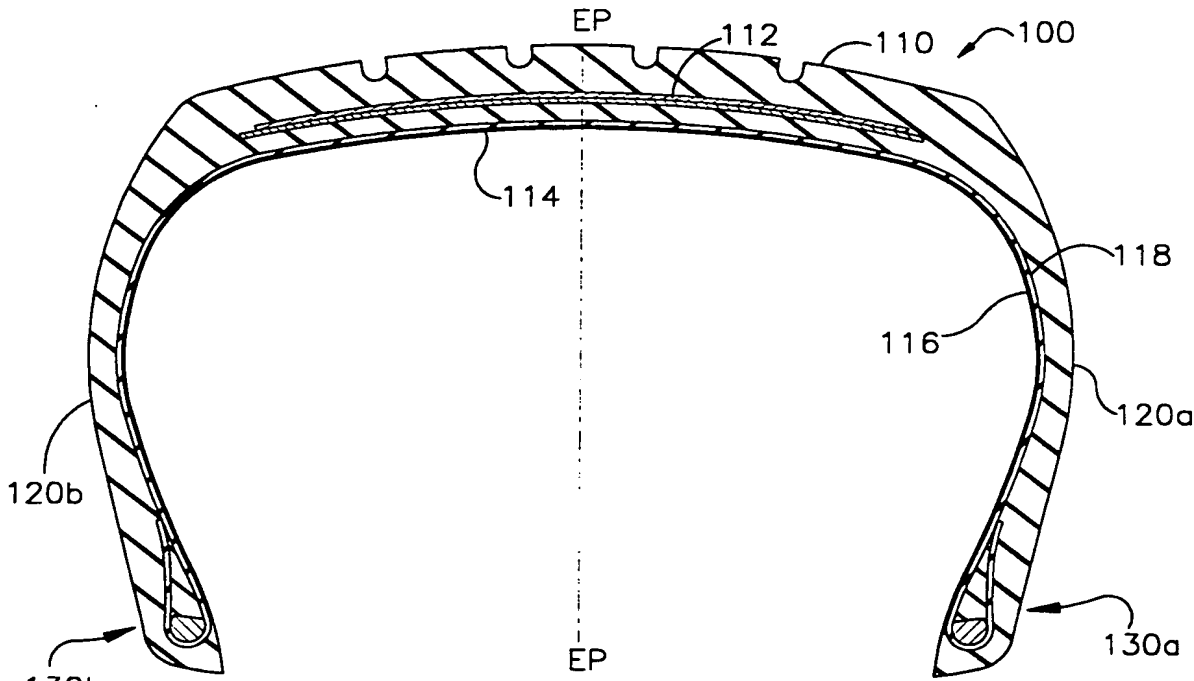


FIGURE 1A
(PRIOR ART)

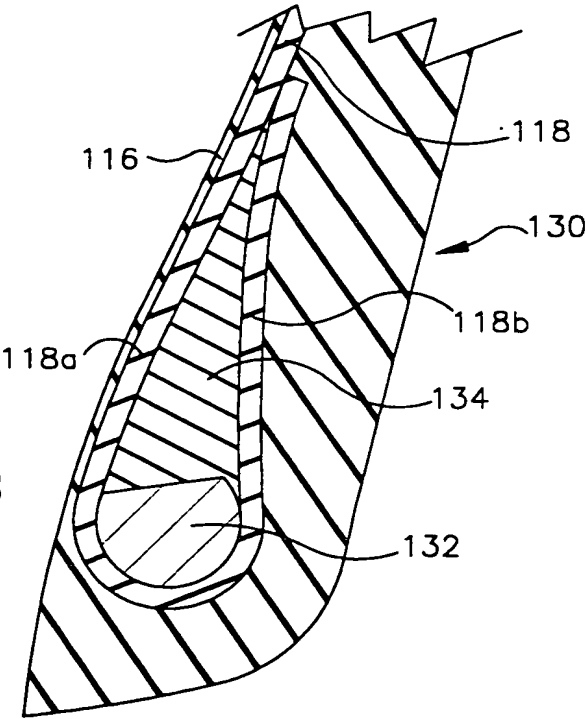


FIGURE 1B
(PRIOR ART)

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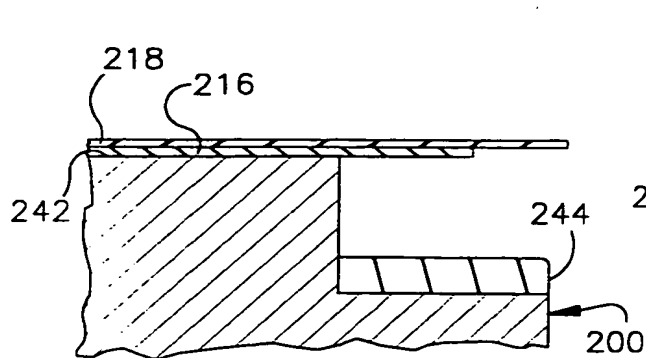


FIGURE 2A
(PRIOR ART)

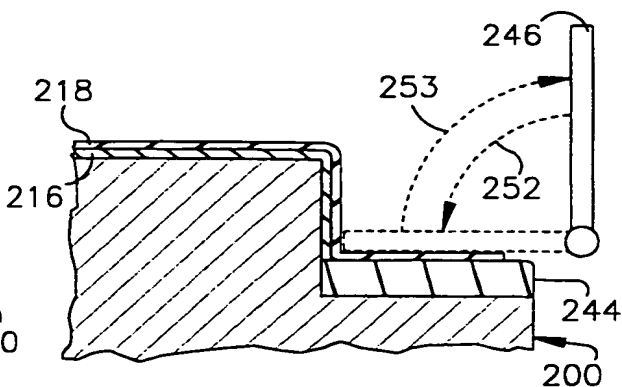


FIGURE 2B
(PRIOR ART)

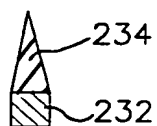


FIGURE 2C
(PRIOR ART)

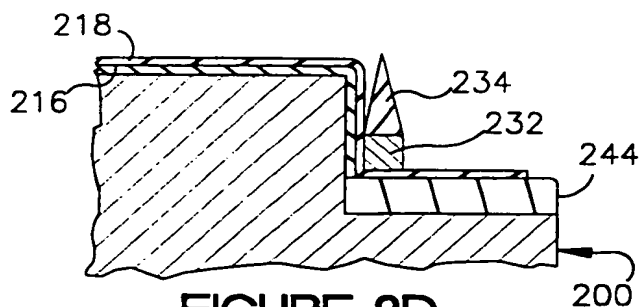


FIGURE 2D
(PRIOR ART)

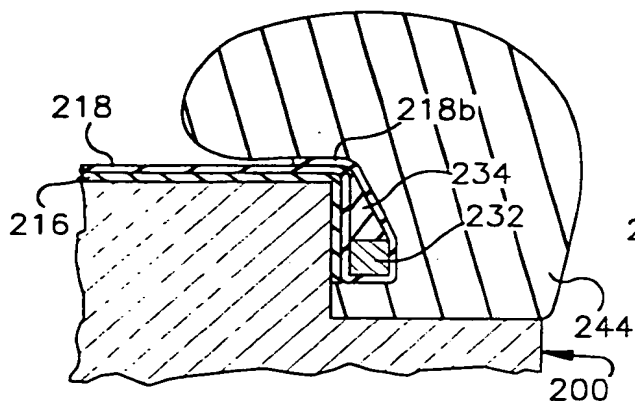


FIGURE 2E
(PRIOR ART)

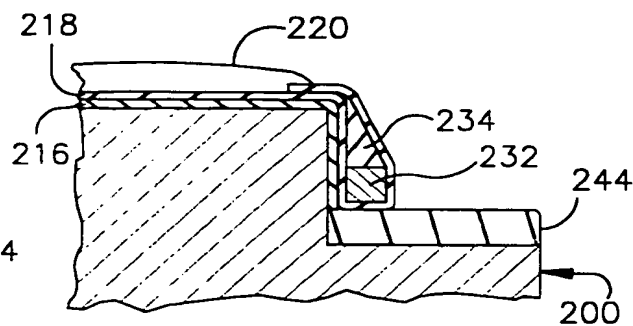


FIGURE 2F
(PRIOR ART)

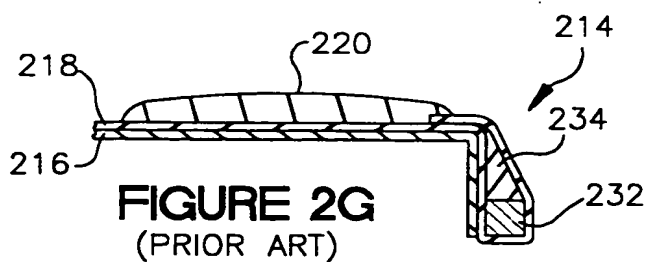


FIGURE 2G
(PRIOR ART)

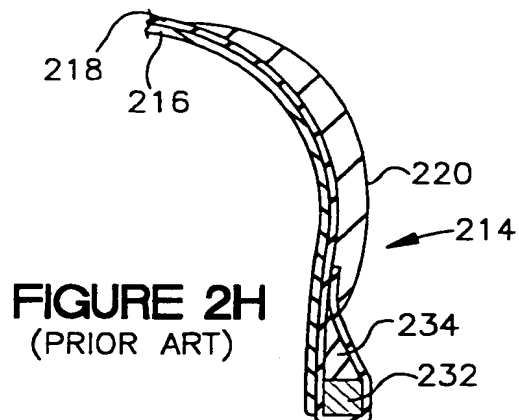


FIGURE 2H
(PRIOR ART)

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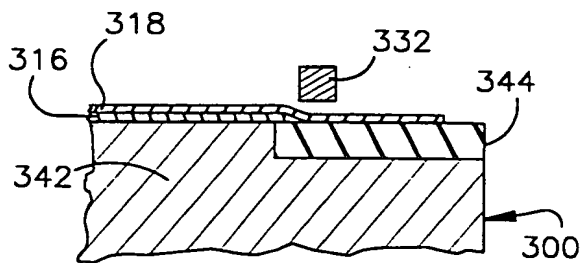


FIGURE 3A
(PRIOR ART)

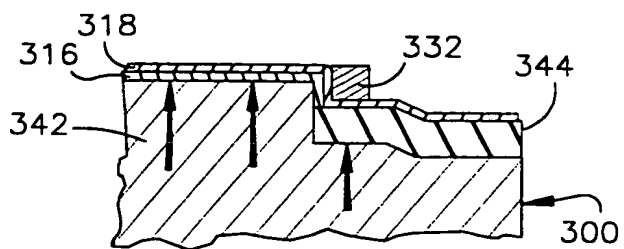


FIGURE 3B
(PRIOR ART)

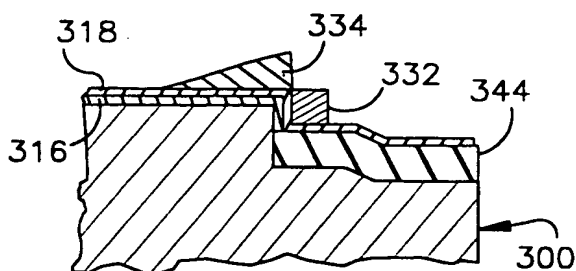


FIGURE 3C
(PRIOR ART)

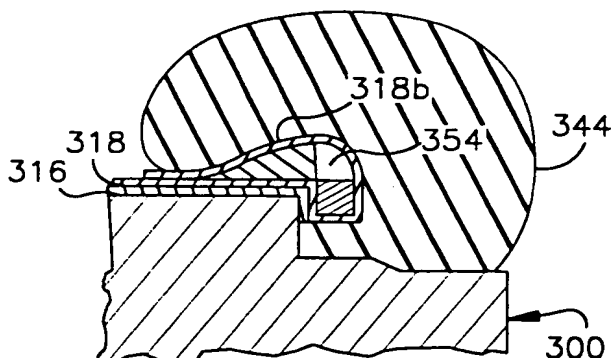


FIGURE 3D
(PRIOR ART)

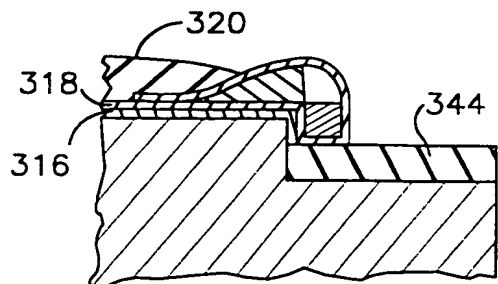


FIGURE 3E
(PRIOR ART)

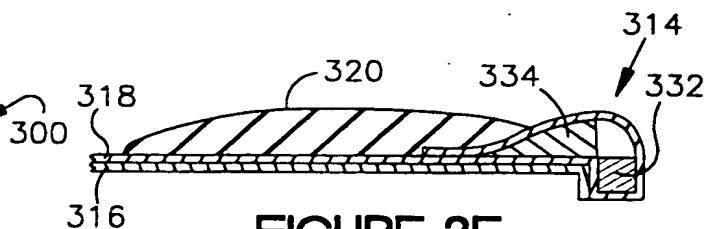


FIGURE 3F
(PRIOR ART)

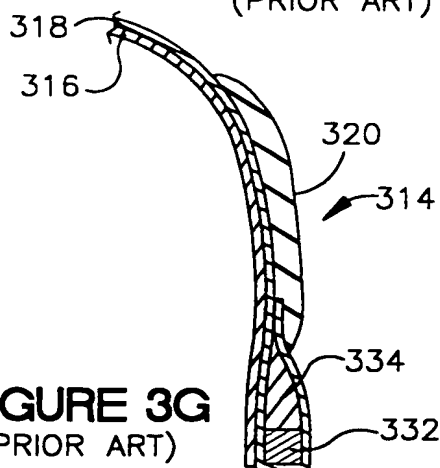


FIGURE 3G
(PRIOR ART)

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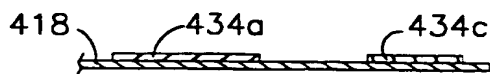


FIGURE 4A

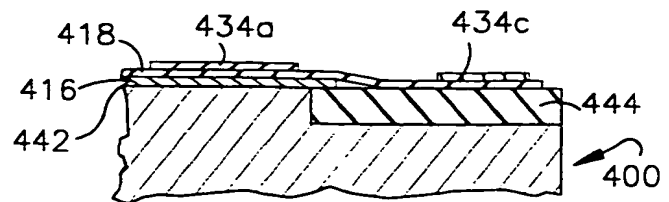


FIGURE 4B

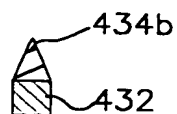


FIGURE 4C

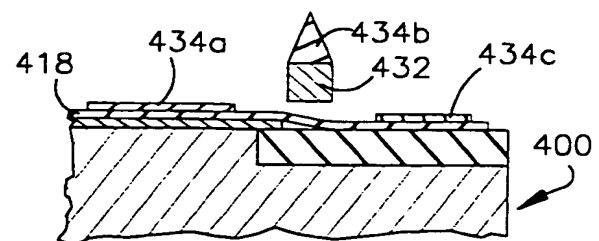


FIGURE 4D

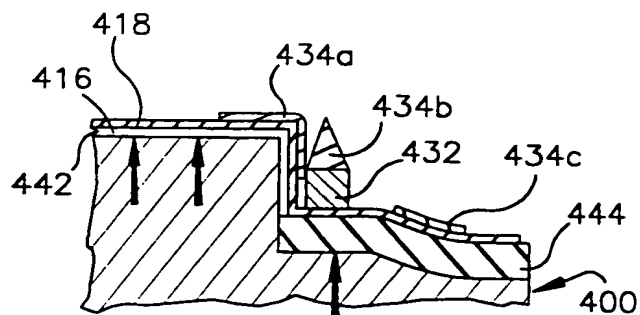


FIGURE 4E

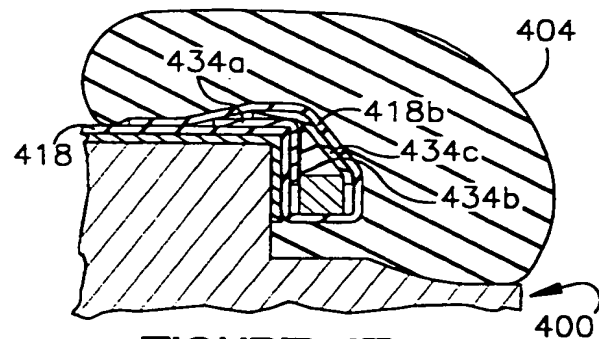


FIGURE 4F

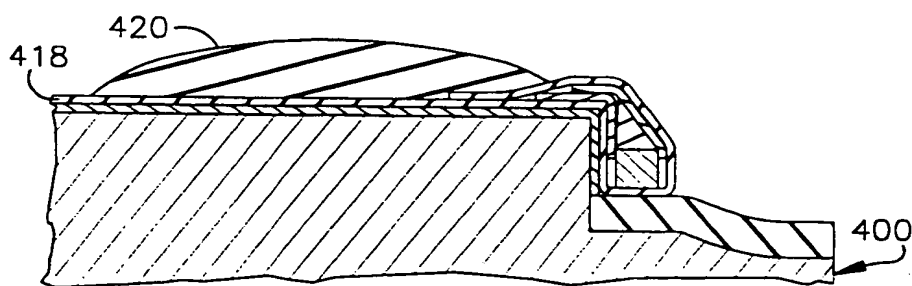


FIGURE 4G

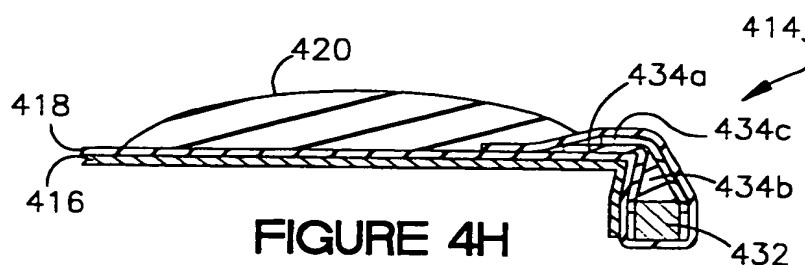


FIGURE 4H

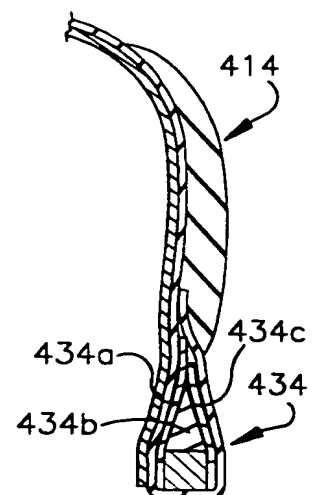


FIGURE 4I

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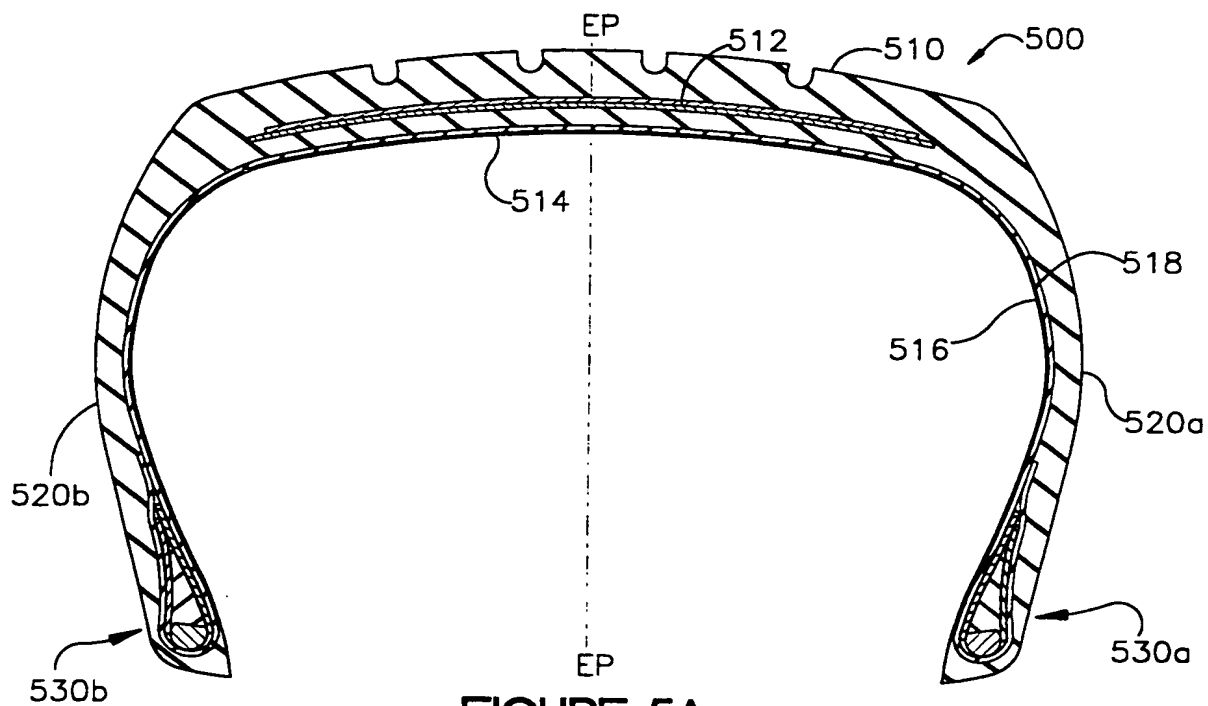


FIGURE 5A

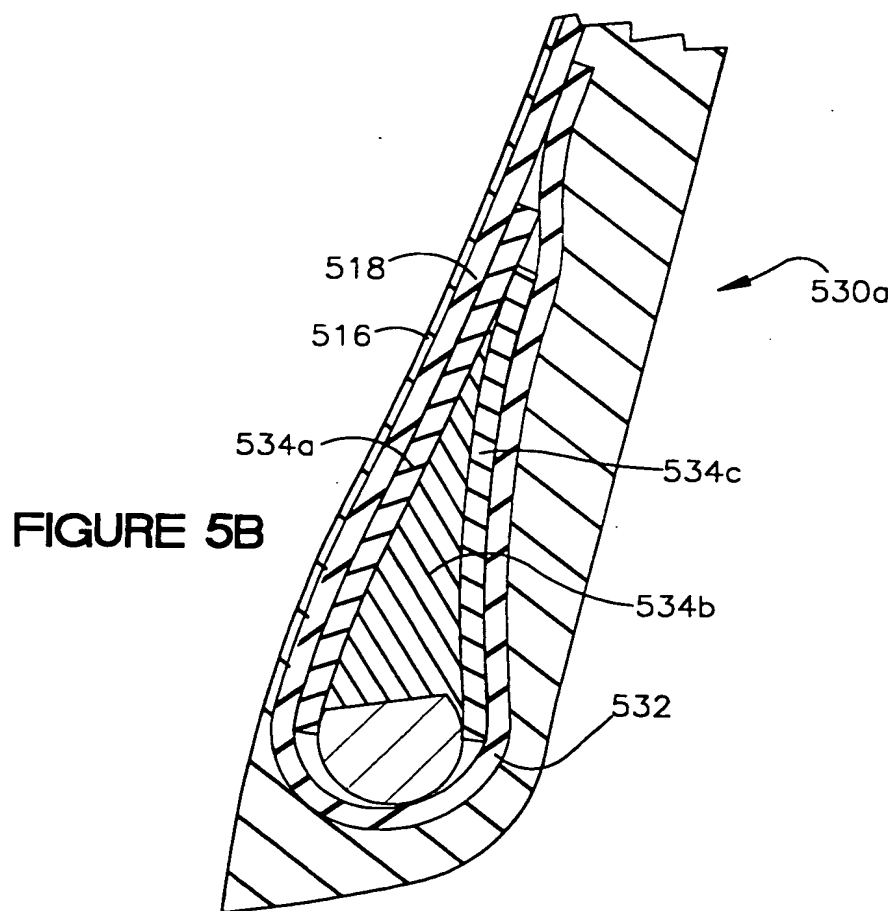


FIGURE 5B

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/28909

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B29D30/20 B60C15/06 //B29D30/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B29D B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

26 July 2000

Date of mailing of the international search report

08/08/2000

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INTERNATIONAL SEARCH REPORT

International Application No

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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International Application No

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